DOCUMENT RESUME

ED 167 186 IR 007 108

AUTHOR Miller, William G.
TITLE Microprocessors as an Adjunct to Statistics Instruction.
PUB DATE 78
NOTE 23p.; Paper presented at the Annual Meeting of the American Educational Research Association (Toronto, Canada, April 1978)

EDRS PRICE MF-$0.83 HC-$1.67 Plus Postage.
DESCRIPTORS *College Instruction; Computer Assisted Instruction; *Computer Programs; Construction Costs; *Cost Effectiveness; Educational Facilities; Graduate Students; Instructional Aids; Nonparametric Statistics; Programed Instruction; *Statistics; Teaching Machines; *Teaching Methods

ABSTRACT

Examinations of costs and acquisition of facilities indicate that an Altair 8800A microcomputer with a program library of parametric, non-parametric, mathematical, and teaching programs can be used effectively for teaching college-level statistics. Statistical packages presently in use require extensive computing knowledge beyond the students' and instructors' desired needs. Simplified access is available through use of microprocessor systems. Costs of different microprocessor systems vary with performance, operational specifications, and quality. Cost comparisons are also difficult to make between microprocessor systems and mini-, macro-, and mega-systems, as well as large systems. Consideration must be given to software, acquisition, tangible and intangible benefits to users, and various other criteria. Some statistical instruction programs, used primarily to generate sample problems for homework or tests and to analyze data found in textbooks or illustrate statistical relationships, demonstrate the possibilities. To fully capitalize on the microcomputer revolution, microcomputer manufacturers must assume greater responsibility for equipment, maintenance, service, and standards for programming languages. Institutions must rethink resources and planning, and the impact of microprocessor use on students. (CWM)

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MICROPROCESSORS AS AN ADJUNCT TO STATISTICS INSTRUCTION

by

W. G. Miller

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Microprocessors As An Adjunct to Statistics Instruction

W. G. Miller
Southern Illinois University

Introduction

Undergraduate and graduate programs in colleges and universities frequently involve requirements of introductory and advanced statistics coursework. Not many years ago, such courses required laborious computation by hand or on rotary calculators. With electronic calculators, some of this labor has obviously been alleviated. Advanced courses usually require computations that go beyond the reasonable use of calculators. Advanced courses, therefore, also often include introductions to use of computers and software written for statistical analyses. Older packages such as those developed by Veldman, the Biomedical (BMD) programs, and SPSS have been the primary source of analysis for many students. More recent packages such as the SAS, IMSI, and CADA (Bayesian Programs) have enhanced the repertoire of statistical programs available. Currently, much effort is being expended on making these packages truly interactive in use. With the exception of the CADA package, few of these systems are written for implementation on small computers. Because of this, the student must become familiar with the job control language and processing characteristics of fairly complex host machines. In addition, the statistical packages often require extensive control card preparation and program parameter familiarization for their use. The typical student must learn far more about computing than he or she wants to know, just to learn statistics! What is clearly

desirable, from an instructional point, is to focus on statistics and not computing.

From the student viewpoint, use of a computer to analyze data should involve no more than:

1. Turning on the machine
2. Loading a program by typing the program name
3. Responding to program prompting for information
4. Turning off the machine

Actually, steps one and four may be eliminated where computer use is frequent.

It is the contention of the writer, that such simplified access is currently available to students (and faculty) through use of microprocessor systems. What follows is a description of such systems and current and potential applications available. Also, there is a discussion of the problem in assessing the cost effectiveness of this approach and potential problems in use of microprocessors for statistics instruction.

Configurations and Costs

Figure 1 presents three microprocessor equipment configurations and estimated costs. Configuration I is a "starter" system sufficient for use in teaching statistics using programs stored on cassette tapes. This is the system employed in use of the Altair Statistics Programs package to be described later. Configuration II includes a "floppy disk" system representing an optimal single-user configuration. Configuration III is a full-blown multi-user mass storage system with capabilities rivaling (or exceeding) most large centralized university systems for sophistication of operating systems. Cost estimates are based on assembled, tested, and delivered components. Considerable savings are possible, of course, using

Figure 1 - Representative Microprocessor Configurations

	Device Description	System I	System II	System III
1.	Z80/8080A/8085/CPU, power supply, cabinet, motherboard, vectored interrupt, control panel.	$1,000	$1,000	$1,000
2.	RS232 or 20 ma current loop I/O	(1) 250	(1) 250	(9) 1,000
3.	16K Eprom Memory		1,000	1,000
4.	Kansas City or Tarbell Cassette I/O	(1) 250	(1) 250	(2) 500
5.	16K Dynamic Memory	(1) 800	(3) 1,400	(6) 2,800
6.	Cassette Tape Machine	(1) 150	(1) 150	(2) 300
7.	Hardcopy Control Terminal	1,000	1,500	1,500
8.	Cathode Ray Terminal		(1) 1,000	(8) 8,000
9.	Floppy Disk Controlled + Disk		1,000	1,500
10.	Disk Drive and Controller			6,000
11.	Line Printed			5,000
12.	Extended Basic		200	200
13.	Fortran			200
14.	PL/1			200
15.	Time Sharing System			800
	TOTAL SYSTEM COST:	$3,450	$7,550	$30,000

kits. The author's configuration (Configuration I) actually cost about $2,000 by assembling kits. Costs presented represent the highest cost equipment. Since the microprocessor market is extremely competitive, individual components purchased separately may effect as much as 25% reductions. There are obvious quality differences between a Radio Shack $600 computer and a Cromesco machine of similar configuration costing four times as much although the naive buyer may not discern the difference by their operational specifications. As in most cases, you get what you pay for. A $3,000 system purchases wisely, may be continuously expanded to the larger configuration. System II, for example, differs from Configuration I by the addition of a floppy disk, CRT terminal and memory (both programmable and read-only). This System II configuration would allow the degree of operational performance idealized in the introduction, but for one student at a time. Configuration III would permit up to eight concurrent users and over 74 million bytes of fast-access online storage (e.g., the Ohio Scientific Computing System).

Comparison of microprocessor systems to mini, macro, and mega-systems is difficult. Microprocessor systems are not typically configured with seven or nine track tape drives whereas larger machines are. Micro's have not formally developed use of high speed cache memories although newer CPU chips now include random access memory integrated with the processor. Direct memory access methods within microprocessor architecture provide for capability of multiprocessor configurations, particularly with some processors dedicated to input/output and, like the North Star Corporation, some dedicated to arithmetic processing.

Software, as usual, lags hardware development. For example, Cromemco has advertised availability of a disk-based BASIC for over a year but has yet to deliver. Sixteen-bit microprocessors and 12-bit processors emulating Digital Equipment Corporation PDP-11 and PDP-8 machines do promise capability of using existing DEC software. Few application systems are highly sophisticated for 8-bit processor but are being rapidly developed.

Cost comparisons are even more difficult to make between large systems and microprocessors. To accomplish such a comparison requires agreement on a number of criteria. For example, assume one is comparing the cost of installing an attached processor to an IBM 370/158 to service 38 interactive terminals by means of a virtual memory operating system supporting CMS (Cambridge Monitor System). Costs of such an expansion is approximately $500,000 for the attached processor and $250,000 for the multiplexor and modems for voice grade communication lines. To compare such an acquisition for expansion requires a number of assumptions about users. For the applications represented by many universities, we may assume, for example, that 80% of the terminal usage is by beginning students learning BASIC, FORTRAN and PL/1 programming. Assume the other 20% are faculty utilizing the terminals to write FORTRAN or BASIC programs or remotely submit data to library programs such as SPSS. Disallowing cost of the terminals, which is approximately the same for either microprocessors or large systems, the cost of the above system expansion is roughly $20,000 per terminal. Note that this has

not included the cost of additional disk storage, memory, channels, telephone line rental and installation nor maintenance contracts, system programming personnel, space, etc. It represents, therefore, an unrealistically lower-limit cost. Assume that instead of this IBM system expansion, you were considering an alternative of purchasing 38 microprocessors, say, for sake of comparison, a configuration of Challenger III processors from Ohio Scientific; costs would include (excluding terminals as before):

a) a 32K byte machine with Z-80, 6800 and 6502A processors, dual floppy disk drives storing 500,000 bytes, serial interface, disk operating system and extended BASIC for $3,481.00.

b) 32K additional random access memory (North Star) at $920.00

c) 74 megabyte disk from Ohio Scientific at $6,000.00.

d) FORTRAN and PL/1 Software, e.g., Microsoft - $1,000.00.

Thus, for about $12,000 each, one would acquire personal computers for each user and, in addition, acquire nearly 3 billion bytes of disk storage as a bonus, and save a quarter of a million dollars! Well, you say, there obviously must be a catch. Sure, we have not included a number of other criterion, e.g.:

a) speed of processing

b) access to files stored on nine or seven-track tape

c) access to numerous library programs maintained on system files of larger machines

d) resale potential of each configuration (obsolescence)

3) high speed printing of large reports.

But re-examine our initial assumptions about the users! How many beginning students utilize tape media and large packages of software? What is the tradeoff in learning to use a system relatively free of complex control and file creation procedures? Does one 370/158 processor actually execute 38 jobs faster than 38 independent microprocessors?

It may be argues that the savings in acquiring microprocessors is more than sufficient to pay the cost of developing comparable software utilized by over 90% of the users. In addition to the tangible cost savings, there are a number of intangible benefits from use of microprocessor systems. To list a few:

a) Reduction of the "black box mystique". Users are in control of their "own" machine and not at the end of an umbilical cord to some unknown "monster" buried in the bowels of some remote building.

b) Greater accessibility to students and faculty at locations under control of each department rather than some "centralized" authority.

c) Control of access priority to the equipment by the individual departments.

d) Ability to enhance the computing facility by those who actually generate grants rather than loss of those funds through purchase of "services" to another unit.

e) Flexibility in tailoring equipment within a department such as adding analog/digital circuits for data acquisition and real-time experimentation.

f) Greater exposure of faculty and graduate students to computing capabilities by the very presence of the equipment.

We have noted that software development has lagged behind hardware development. For use of microprocessors in the teaching of statistics,

it is important that this gap be closed. The following section reports one effort in that direction.

Instructional Use of a Microprocessor to Teach Statistics

An Altair 8800A system assembled by the author was used to develop a library of programs, written in BASIC, for use in teaching elementary and advanced statistics to graduate level students. The courses taught were offered through the Guidance and Educational Psychology department at Southern Illinois University and included students from both the physical and social sciences. Applications focused on were primarily in education and psychology. Appendix A lists the contents of the Altair Statistics Programs book which contains descriptions of the programs, instructions for use, and program listings. Programs constructed were written with the use of an 8K byte BASIC interpretor using either 8K or 16K total bytes of memory. Since equipment used was the sole property of the author, students did not have direct access to the computer. A few students, by special arrangement, did run the machine to analyze data to be used in term papers, theses, and dissertations. The primary use of the programs was to generate sample problems for homework or tests. The programs were also used to analyze data found in the textbook and illustrate a variety of relationships not covered by the textbook itself. For example, it was possible to illustrate that a t-test yields the same inference as an F-test by ANOVA of two groups of data containing either independent or dependent samples.

Since a random number generation capability is built into the BASIC language, it was also possible to generate sampling distributions for several statistics and demonstrate effects of sample size. By generating sample problems and tests utilizing the generation of random number sets, the author increased the degree to which students worked independently in completing assignments.

Figure 2 represents the test-generating application of the microprocessor. In this example, each student receives a different set of values to complete a two-way, fixed effects, analysis of variance. Answers are, of course, generated concurrently for use by the instructor in grading the student efforts. Using forms with performances, the programs are written or easily modified to print questions and answers on separate pages.

Figure 3 represents the use of another program, a program for recursive path analysis, to demonstrate that path coefficients may be estimated by standardized regression coefficients. This program interactively requests the user to explicate the path model by entering numbers representing the resultant and causing variables. Students previously introduced to multiple regression theory are thus able to see that path analysis is a repetition of numerous, hierarchically arranged, multiple regression analyses.

The programs represented by the ASP library are, it may be acknowledged, a rather "brute force" beginning of what will rapidly become one of many software libraries available to instructors and researchers. The enhancement of such libraries through use of disk-based operating systems will clearly lead to systems equal to or superior to present systems such as SPSS available only on larger computers.

Figure 2 - Sample Test Problem

```
RUN
LESSON 14
NO. OF STUDENTS?  1
ANALYZE THE DATA BELOW USING THE FIXED EFFECTS MODEL
USE THE .Ø5 LEVEL OF SIGNIFICANCE
MAKE A GRAPH OF CELL MEANS TO SHOW POSSIBLE INTERACTION


ROW 1 DATA
COLUMN 1          COLUMN 2          COLUMN 3
-------------------------------------------
       4                 4                 Ø
       1                 1                 6
       5                 3                 6
       Ø                 8                 9
       7                 8                 4

ROW 2 DATA
COLUMN 1          COLUMN 2          COLUMN 3
-------------------------------------------
       6                 8                 2
       8                 6                 3
       9                 6                 3
       9                 6                 7
       5                 1                 7

ROW 3 DATA
COLUMN 1          COLUMN 2          COLUMN 3
-------------------------------------------
       4                 3                 3
       Ø                 2                 6
       3                 4                 4
       3                 2                 Ø
       5                 8                 2


-----------------------------------------------------------
SOURCE          DF              SS              MS              F
CELLS            8              78.8ØØ2
COLS.            2               2.53326         1.26663         .19127
ROWS             2              45.733          22.8665          3.453
RXC              4              3Ø.5339          7.63347         1.15271
WITHIN          36              238.4            6.62222
TOTAL           44              317.2
-----------------------------------------------------------

OK
```

Figure 3 - Recursive Path Analysis

```
2ØØØ REM ROUTINE TO RECONSTRUCT R MATRIX FROM PATH COEFFICIENTS
2ØØ5 D2-Ø
2Ø1Ø T=N+X:FORI=1TOT:E(I.I)=1:NEXTI
2Ø11 IFX=1THEN2Ø2Ø
2Ø12 FORI=1TOX-1:FORJ=I+1TOX:E(C1(CI).X1(J)=R(X1(I),X1(J))
2Ø13 R(X1(J),X1(I))=E(X1(I),X1(J)):NEXTJ:NEXTI
2Ø2Ø FORI=ITOM:W(C(I.1).C(1.2))=P(1):W(C(I.2).C(I,1))=P(I)
2Ø3Ø NEXTI
2Ø4Ø FORI=ITOT:FORJ=1TOT:IFI=JTHEN2Ø8Ø
2Ø5Ø FORI=ITOJ-1
2Ø51 FORL2=1TOM:IFC(L@.1)=JANDC(L2.2)=LTHEN2Ø55
2Ø52 NEXTL2
2Ø53 GOTO2Ø56
2Ø55 E(I,J)=E(I,J)+W(J,L)*E(I.L)
2Ø56 NEXTL
2Ø57 E(J,I)=E(I,J)
2Ø8Ø NEXTJ:NEXTI
2Ø9Ø PRINT:PRINT"REPRODUCED CORRELATION MATRIX":PRINT
21ØØ FORI=ITOT:FORJ=:TOI:PRINTE(I.J),:S=S+ABS(R(I,J)=E(I,J))
21Ø5 1FD2 ABS(R(I,J)-E(I,J))THEND2=ABS(R(I.J)-E(I.J))
211Ø NEXTJ:PRINT:NEXTI:PRINT
212Ø PRINT"AVERAGE ABSOLUTE DIFFERENCES BETWEEN OBSERVED"
213Ø PRINT" AND REPRODUCED COEFFICIENTS=";S/(T*(CT-1)/2)
214Ø PRINT"MAXIMUM ABSOLUTE DIFFERENCE FOUND=";D2
OK

RUN
ENDOGENOUS RECURSIVE PATH ANALYSIS

NO. OF ENDOGENOUS VARIABLES? 3
NO. OF EXOGENOUS VARIABLES? 1

ENTER THE UPPER TRIANGULAR MATRIX OF CORRELATIONS
AMONG THE 4 VARIABLES
ROW 1
? 1
? .35
? .42
? .18

ROW 2
? 1
? .22
? .43

ROW 3
? 1
? .34

ROW 4
? 1

ORIGINAL CORRELATION MATRIX
 1
.35          1
.42          .22         1
.18          .43         .34         1
```

Figure 3 - contd.

```
GIVE ROW NO. OF EACH EXOGENOUS VAIRABLE.
EXOGENOUS VARIABLE 1 ROW=? 1

TO DESCRIBE YOUR MODEL REQUIRES YOU TO ENTER, FOR EACH
ENDOGENOUS VARIABLE, THE ROW NO. OF THE VARIABLE
CONSIDERED RESULTING FROM ANOTHER, AND THE ROW NO. OF
THE VARIABLE "CAUSING" THE FIRST.  TO END ENTRY OF
THESE RELATIONSHIPS, ENTER 9999.

RESULTANT VARIABLE? 2
CAUSING VARIABLE? 1

RESULTANT VARIABLE? 3
CAUSING VARIABLE? 1

RESULTANT VARIABLE? 3
CAUSING VARIABLE? 2

RESULTANT VARIABLE? 4
CAUSING VARIABLE? 1

RESULTANT VARIABLE? 4
CAUSING VARIABLE? 2

RESULTANT VARIABLE? 4
CAUSING VARIABLE? 3

RESULTANT VARIABLE? 9999

CORRESPONDING PATH COEFFICIENTS FOR VARIABLE 2
 .35
SQUARED MULTIPLE CORRELATION= .1225


INDEPENDENT VARIABLES RELATED TO (CAUSING) 3
 2              1
CORRESPONDING PATH COEFFICIENTS FOR VARIABLE 3
 .0831909       .390883
SQUARED MULTIPLE CORRELATION= .182473


INDEPENDENT VARIABLES RELATED TO (CAUSING) 4
 2              3              1
CORRESPONDING PATH COEFFICIENTS FOR VARIABLE 4
 .394435        .286069       -.0782013
SQUARED MULTIPLE CORRELATION= .252794


REPRODUCED CORRELATION MATRIX

 1
 .35            1
 .42            .22            1
 .18            .43            .34            1

AVERAGE ABSOLUTE DIFFERENCES BETWEEN OBSERVED
AND REPRODUCED COEFFICIENTS= 1.49012E-08
MAXIMUM ABSOLUTE DIFFERENCE FOUND= 5.96046E-08
OK
```

What will encourage the development and enhancement of instruction and research software for microprocessors? One obvious answer is, of course, the profit motive. As software is purchased, it provides the capital for further development and refinement. A second answer will by the association of professionals owning, or responsible for access to, machines used in instruction and research. A National Microcomputer Software Exchange and Development Association, perhaps a subsidiary or special interest group within AERA or the Association for Computing Machinery, would permit low cost exchange and distribution of software developed by individuals. Use of low charges for acquisition would provide "seed" money to contract for the development of specialized software beyond the scope of individual efforts..

Perspectives

In order to fully capitalize on the microcomputer revolution, a number of changes must occur or will occur. These are:

a) Readjustment of institutional planning and thinking about resources. Most colleges and universities are oriented to acquisition of large, centralized computing facilities. The fear of inordinate expenditures through individualized department purchases, rapid obsolescence potential, lack of skilled personnel available to make effective use of distrubuted processors and loss of administrative control are factors perpetuating dependence on centralized systems. It is peculiar that such similar constraints are not nearly as evident in the purchase of office

equipment and laboratory equipment often costing much more! Central administrators must be provided more literature and instruction concerning alternative computing arrangements.

b) Greater responsibility on the part of microcomputer manufacturers is required. Many firms selling equipment promise software and services they connot deliver. The author's experience with CROMEMCO equipment is such an example. Purchasers of equipment must insist on performance bonds and acceptance testing before payment of received equipment.

c) Maintenance and service organizations are sorely needed. It is not unusual to wait several months for equipment repairs by vendors.

d) Standards need to be adopted by microprocessor manufacturers for higher level languages such as BASIC, FORTRAN and PL/1. While high similarity exists among versions available, the idiosyncratic nature of only a few instructions can cause large, unnecessary costs inconversion from one system to another.

e) Consideration must be given to the impact that training through use of microcomputers will have on students. For example, will they be more or less marketable if they have not learned the use of SPSS but rather something like ASP? Will we foster an undeserved reliance on computers for data analysis and undermine learning the conceptual basis for the analyses?

Resources for Further Information

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